OBSERVATIONS ON SOUND PRODUCTION AND SOUND CONDUCTION ALONG THE RESPIRATORY TRACT.

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In a preliminary communication[1] on the transmission of sound by the bony framework of the thorax and by adjoining osseous structures, I called attention to the tubular-like breathing which is to be heard during the respiratory excursion at certain named areas not previously considered.

Up to the present time the chief claim that those observations may have upon our interest is that they are striking examples of the sound conducting ability of the bony framework of the body, particularly the thorax, and as such, will necessarily direct our attention to a more extensive consideration of the relationship between the various auscultatory phenomena, their manner of production, and source of origin.

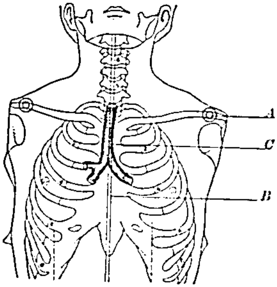

Fig. 1.—*A*, acromion area of bronchial breathing; *B*, median line of the body; *C*, position of the trachea as compared with the median line of the body. (J. C. Blake, Amer. Journ. Med. Sci., 1899.)

My first communication dealt chiefly with the finding of (1) tubular breathing at the acromial end of the clavicle; (2) tubular breathing over the uppermost portion of the spine—this sound I now wish to designate as cavernous breathing (*vide infra*); and (3) cavernous breathing also heard over the occipital and other bones of the cranium (Figs. 1 and 2).

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[1] The Role Played in Auscultatory Signs of the Respiratory System by the Sound-conducting Property of the Bony Framework of the Thorax.—Amer. Journ. Med. Sci., December, 1910.

On first hearing this sound one may object to the term "cavernous" as applied here, yet the sound is a true cavernous sound, and such objections are therefore not valid.

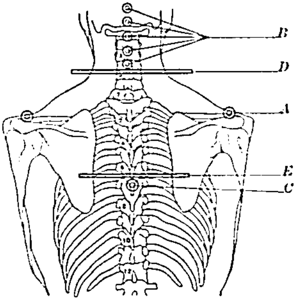

FIG. 2.—*A*, bronchial breathing heard over the acromion area: *B*, cavernous breathing heard above the recognized height; *C*, bronchial breathing heard below the recognized height; *D*, level of the fifth cervical vertebra where bronchial breathing is supposed to end; *E*, level of the fifth dorsal vertebra where the bronchial breathing is supposed to end.

SOURCES OF THESE SOUNDS.

Since up to the present we have only concerned ourselves with respiratory sounds heard from within the thorax proper, and rarely over the trachea, and since the generally accepted theory is that all sound production begins at the larynx, and also finding that bones are such excellent conductors of sound waves, it was a natural inference that the sounds heard at the above-mentioned areas had their beginning in the larynx and trachea.

This was the view accepted at the time of the communication referred to. But further investigations upon the origin and transmission of these auscultatory findings prove that sound production does not begin at the larynx, and that other factors, to be here considered, play a distinct role in determining the quality and quantity of sound heard.

In Fig. 3 I have arbitrarily divided the course of the upper air passage into spaces *A*, *B*, *C*, and *D*, representing the nasal fossa, the oral cavity, the laryngeal space, which includes the larynx and the trachea. Each of these represents an element in sound production and will be here considered.

Space *A*. The nasal fossæ are bounded above by a roof composed of portions of the nasal, frontal, ethmoid, and sphenoid bones and the basilar process of the occipital bone. The floor is formed by the palatal bones, the outer walls by bones of the face, and the entire space is divided by a bony and cartilaginous septum.

Here we have an irregularly triangular space, bounded by bony walls and divided by a septum. Through this divided chamber passes a volume of air (about 500 c.c.) with each respiratory act, under constant pressure. The friction thus caused along its walls, including the turbinate shelves, necessarily sets up sound vibrations. These vibrations are taken up by the bones which enter into the formation of the walls of this bony cavity, and over some of them the sounds named are to be heard.

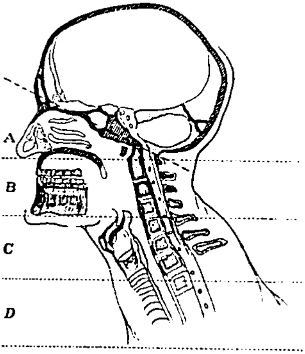

FIG. 3.—Upper air passage divided into the nasal fossa, *A*, the oral cavity, *B*, and the laryngeal and tracheal spaces, *C* and *D*.

Space *B*. The bony elements which may influence the production of sounds under consideration in this space are the teeth, the hard palate, and the posterior wall of the pharynx, which is composed of the cervical vertebræ. A volume of air on inspiration, passing with a definite amount of friction against the teeth, the hard palate, and striking the posterior pharyngeal wall, is certain to create a considerable number of sound waves.

Compared with space *A*, space *B*, as will be shown, plays a less important part in the sound production with which we are here concerned.

Space *C*. In this space lies the important organ of voice production, the larynx. Its cartilaginous walls, their peculiar arrangement, the positions and vibrations of the vocal cords make this organ an important source of sound vibrations, subject, however, within limitations to certain influences.

Space *D*. In this space lies the trachea, which, by virtue of being a cartilaginous and membranous tube, with an interior which has an undulating surface, itself forms an efficient excitor of sound waves. Its large share in sound production also enters into this consideration.

From what has been thus far stated, it is obvious that I regard spaces *A* and *B* of sufficient importance to warrant a consideration of the influence which they have upon auscultatory phenomena of the chest.

CONDITIONS MODIFYING SOUNDS.

Over the occipital area, nasal breathing, mouth closed. By applying the bell of a stethoscope (about the size of the Ford stethoscope) to the occipital bone, below its protuberance, one hears a pure type of cavernous breathing. The expiratory is louder than the inspiratory sound. The reasons for this are, I believe, that the outgoing volume of air strikes the roof of the nasal fossa more directly and more forcibly, and it may also be largely due to the position of the vocal cords, which are closer and vibrate more during expiration.

Mouth Breathing, Nostrils Closed. Without removing the stethoscope, and having the subject open the mouth and at the same time close the nostrils, one will find that the cavernous respiratory sound has almost disappeared.

The reason for this is, that the source of origin of the sound, the nasal fossa as a resonating chamber, has been eliminated. A distant and weaker sound is, however, still heard, and its origin may be from one of two or perhaps from both sources. It may be the faintly transmitted sound from that portion of the spinal column which gets its sound from the larynx, or it may be produced by the moving air in space *B* striking the posterior pharyngeal wall and at the same time setting in motion the residual air in space *A*, creating lesser sound waves and fainter sounds.

Mouth Breathing, Nostrils Open. Having the mouth and nostrils both open gives, on auscultation at the same areas, a louder sound than when the nostrils are closed, but a sound not nearly so large in volume nor high in pitch as when the mouth is closed.

Influence of Nasal and Oral Breathing upon Laryngeal and Tracheal Sounds. Sounds heard when auscultating over the larynx, trachea, manubrium sterni, and acromial ends of the clavicles, are much influenced by opening and closing of the mouth. With nasal breathing, when the nasal fossa acts as a reasonating chamber, the characteristic and familiar "bronchial" breathing is plainly audible. Closing the nostrils and opening of the mouth, thus eliminating the nasal resonator, reduces the volume and pitch of sounds at all of the above-named areas.

Heretofore it has been generally conceded that the production of sound heard over the respiratory organs begins at the larynx. The foregoing observations seem to prove conclusively that a definite amount of sound is created before the larynx is reached. Also that on eliminating the nasal resonating chamber, the various respiratory sounds become weaker, thus showing that the nasal resonator actually does add to the "sound total."

Part Played by the Larynx. During inspiration the downward moving volume of air, carrying with it a certain amount of sound acquired in the nasal resonator, reaches the larynx and there takes up more sound. During expiration, the upward moving volume of air, already charged with sound waves, enters the nasal resonator and there reverberates. So that the column of air which is to enter the larynx at both inspiration and expiration, already is carrying an appreciable amount of sound, and here receives more. How much more, and what actual part the larynx itself plays in the production of auscultatory sounds, I have attempted to determine by studying the physical signs in two tracheotomy cases.[2]

One of these breathed through a tracheotomy tube, and the other through a large tracheal fistula. Here the larynx took no actual part in sound production.

CASE I.—Tracheotomy tube inserted at the second and third cartilages.

Over Cranial Bones. When patient was breathing through the tracheotomy tube only, having closed the nares and mouth, no sounds could be detected at the occipital area, nor anywhere above the level of the tracheotomy tube. Leaving the nose open, which permitted the passage of a limited amount of air through the nasal resonator, was followed by loud cavernous breathing over the entire head and upper portion of spinal column down to the level of the tracheotomy tube. The sounds were almost as distinct over the frontal bone as over the occipital and parietals.

Over Trachea. When the nares were closed and the nasal resonator entirely eliminated, the tracheal sound was softer than when the nares were left open and a small amount of air could pass through the nasal fossa which acted as a resonating chamber.

Over Sternum. At the manubrium sterni, when the patient breathed naturally and air was rushing in through the tracheotomy tube, and some through the nasal fossa, the usual "bronchial" sound was heard. The expiratory and inspiratory sounds were nearly of equal length. Closing of the nares, thus eliminating the nasal resonator, was followed by a weakening of the sounds, of which the expiratory was considerably louder than the inspiratory sound, probably because of backward reflection of sound waves in the trachea resulting from obstruction by the tube.

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[2] Through the kindness of Dr. Chevalier Jackson and Dr. Ellen J. Patterson, I was afforded the opportunity of studying these cases.

At the Acromion Areas. With the nares open, and nasal resonator acting, the transmitted bronchial breathing was clearly heard with equal strength on both sides. Closing of the nares made the sound faint and almost inaudible.

In my first communication on this subject I called attention to the fact that the bronchial breathing over the right acromion area was louder than on the left, and also that by auscultating with the median line as a starting point, the tracheal sounds over the manubrium sterni and apices extended to the right side. This observation I have since been able to confirm in the greater number of my examinations, but not in all. Whether in those individuals in whom the acromion sounds are of equal values the trachea is situated nearer the median line, I am at present unable to say.

Right Apex Anteriorly (Bowles' stethoscope). Nose open, vesicular sound quite distinct; nose closed, no sounds.

Left Apex Anteriorly. Nose open, vesicular sound clear; nose closed, sounds very faint, almost inaudible.

Right Apex Posteriorly. Nose open, inspiratory and expiratory sounds audible; nose closed, inspiratory vesicular sound clear, expiratory sound inaudible.

Left Apex Posteriorly. Nose open, inspiratory and expiratory vesicular sounds audible; nose closed, inspiratory vesicular sounds only are heard.

Over Middle of Chest. The characteristic normal vesicular sound is not present. Instead, one hears a rather rough interrupted vesicular type of breathing at some areas, while at others hardly any sound is heard.

At Base of Lungs. On the left side the sounds are better heard than on the right. By using Bowles' resonating stethoscope, when the nares were left open, I could detect both the inspiratory and expiratory sounds. With closure of the nostrils the inspiratory sound alone was audible.

Speech. These patients make attempts at speech by closing of the tracheotomy tube or fistula with their fingers, and during expiration set the vocal cords or remnants of the same into vibration. The resulting sound, which is a kind of a barking whisper, is transmitted by the osseous structures just as clearly as the normal spoken voice.

CASE II.—This patient breathed freely through a large tracheal fistula, the tube having been discarded.

Cranium. At the occipital area cavernous breathing could be heard when the nares were open or closed. In the other case, when the nares and mouth were closed no sounds were audible; the column of air passing through the tracheotomy tube did not reach the nasal resonating chamber. In this case both the inspired and expired air had access to the nasal cavity, and sound was carried.

Acromion Areas. On the right side, when the fistula was closed, bronchial sounds were distinct; when the fistula was open, the sounds were very faint or imperceptible at times. The left side was the same.

Apices Right and Left. When fistula was closed, the respiratory sound was audible. The sound heard corresponded more to a weak and indistinct bronchial sound than a pure vesicular murmur. When the fistula was uncovered, the respiratory sound was very distant and its character doubtful.

Middle and Lower Lobes. The respiratory sounds were atypical. Bronchial breathing at the median line lacked the quality which characterizes it in the normal, and the vesicular murmur seemed to be replaced by a distant and weaker sound. At the bases posteriorly, inspiration was longer than expiration, and was louder, as the normal vesicular murmur should be. In the axillary aspect of the chest there was a short inspiratory sound and no expiratory sound was audible. Thus, the sounds over most of the chest seemed very distant and weak. Tactile fremitus was imperceptible. Vocal resonance could be heard.

The observations in these two cases show that elimination of the larynx does alter the auscultatory findings, but not sufficiently to change their character. They confirm the previous findings that the sound created within the nasal resonating cavity is a part of the "sound total" which presents itself to us for auscultation over the thorax.

Before my conclusion I wish to note that in this consideration I have dealt with the physiological only. It is needless to say that abnormal configurations and pathological conditions of any of the anatomical parts which enter into this sound-producing and sound-conducting system will respectively modify the findings.

By this study I intended leading up to the consideration of sound transmission in the various pathological conditions.

SUMMARY AND DEDUCTIONS.

In calling attention to the auscultatory findings at the specified areas of the thorax and skull, I desired first to set forth prominently, the sound-conducting ability of the osseous system, particularly the thorax. When it is fully appreciated that sounds emanating at one spot can be transmitted to another, the importance of studying auscultatory signs from such a viewpoint becomes apparent.

Thus, I found that the "bronchial breathing" heard at the acromial end of the clavicle has its origin at the manubrium sterni, which receives sound vibrations from the trachea behind. The cavernous breathing heard over the cranial bones, particularly the occipital, has its source of origin in the nasal fossa which acts as a resonator.

In the nasal fossa, the nasal resonator, a definite amount of sound is produced, and this sound added to the sound wave created along the lower portions of the respiratory tract, makes up the "sound total," which is heard when auscultating.

That the nasal resonator is an active factor in auscultatory sound production is readily appreciated by observing the weakening of the respiratory sounds which occurs when its action is eliminated. From this it is evident that auscultatory sound production does not begin at the larynx. This too, shows that the examiner must take into careful consideration the condition of the nasal resonator, and whether the mouth is open or closed, in the proper interpretation of his auscultatory findings.

The observations upon the tracheotomy cases throw light upon the part played by the larynx, which seems to be of less importance than is generally believed. They show that elimination of the larynx results in modification of the pitch and volume of the bronchial and vesicular sounds, but the essential characteristics of these sounds remain unchanged.

SOME GENERAL CONSIDERATIONS AS TO VISCERAL PTOSIS.

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A ptosis consists, essentially, in a gravitation of an organ, due to some weakness in its normal support. Originally applied mainly to the upper eyelid, and in Dunglison's dictionary of 1874 limited to various ocular conditions, ptosis in recent years has been discussed chiefly as a condition of certain abdominal viscera and, to a less degree, of the heart. While literally applicable to the pelvic generative organs, and properly so, other terms are more commonly employed.

The displacement of an organ outside of the body cavities, to employ a loose expression for an idea which it is difficult to express accurately, is not properly considered as a ptosis. Thus, one does not speak of a ptosis of the thyroid. Obviously, too, the dense, close-fitting walls of the cerebrospinal apparatus prevent the occurrence of this lesion for the corresponding organs.

As stated, ptosis implies a gravitational displacement. Thus, in the perpendicular posture, the displacement is downward and the direction is not necessarily nor, indeed, characteristically altered for other postures. Moreover, the downward displacement is liable to be chronic, and the support of adjoining viscera or of the body wall, more or less regularly for various organs, tends to prevent movements in the horizontal plane, relative to the perpendicular posture of the body as a whole.

A displacement due essentially to encroachment, either of an enlarged organ or of some foreign growth or accumulation, as fluid, etc., or, on the other hand, to traction, as by cicatricial bands, is not essentially a ptosis, even if the displacement is downward, although it is not always practicable to discriminate with regard to the ultimate or complicating causes of displacements of this nature. The definition of ptosis as gravitational, that is, mainly downward in the ordinary vertical posture, must also be qualified to allow for the combination of other forces, as fixed points or planes of resistance, which deflect the organ from a strictly vertical displacement.

Disregarding the female pelvic organs, the conceivable ptoses are as follows: Cardioptosis, pneumoptosis, hepatoptosis, lienoptosis, nephroptosis, gastroptosis, enteroptosis (coloptosis), and more generally splanchnoptosis. The names are purposely given, as some writers substitute mongrel terms for some organs, and the collective ptosis is often designated visceroptosis. These terms cover all of the major organs of the thorax and abdomen. It is hardly conceivable that the suprarenal could be prolapsed without the kidney or the appendix without the cecum, at least.

It is extremely doubtful if the term pneumoptosis, or rather the corresponding conception, is tenable. The lung is a very light, distensible organ, necessarily conforming to the contour of the thoracic wall and floor, and any downward extension of the lung is due to a fault of the diaphragm or of subjacent structures, not to an essential prolapse of the lung itself.

The writer would insist that the term prolapse be limited to a dropping of an entire organ or, at least, of an anatomic unit, as a lobe of the liver or a considerable extent of the colon. Thus, a downward displacement of the heart, not essentially due to a fault of its supports, but to a dilatation, or other form of enlargement, is in no true sense a cardioptosis. This contention will probably not be disputed, indeed, it will more likely be regarded as a truism. It is made in order to support an analogous claim for the stomach. The term gastroptosis frequently occurs in medical literature. Nine times out of ten it applies to the inevitable sagging of the greater curvature of a dilated organ, or, at any rate, it is used without any demonstration that the stomach in its entirety is displaced downward. The term should not be used unless by *x*-ray examination, auscultatory percussion, or some allied method the upper portion of the stomach is also shown to be sagging from its proper level. However, it must be conceded that atonic gastric dilatation, that is, dilatation not due to pyloric obstruction, has many etiologic and pathogenic points in common with gastroptosis.

Hepatoptosis is, in the writer's experience, a very rare condition,